NASA ADVISORY COUNCIL
HUMAN EXPLORATION & OPERATIONS COMMITTEE
NAC HEOC

RICHARD KOHRS

MARCH 8, 2012

NAC HEO Committee Members

- Mr. Richard Kohrs, Chair
- Mr. Bohdan Bejmuk, Co-Chair
- Ms. Nancy Ann Budden (absent)
- Dr. Leroy Chiao (absent)
- Dr. Pat Condon
- Mr. Joseph Cuzzupoli
- Mr. Tommy Holloway (absent)
- Dr. David Longnecker
- Mr. Richard Malow (via Telecon)
- Mr. Bob Sieck

Background

- The NAC Space Operations Committee and NAC Exploration Committee combined into the NAC Human Exploration and Operations Committee and held its first meeting October 31, and November 1, 2011

- The Committee met March 6, and 7, 2012. Open meeting on the 6th and finished up on March 7th.

Agenda

Status of the Human Exploration & Operations Mission Directorate – William Gerstenmaier

Capability Driven Roadmap – John Olson

***Status of the Budget for HEOMD –** Toni Mumford

Exploration Planning, Partnerships, and Prioritization Summary – John Olson

***Status of Space Launch System and Multi-Purpose Crew Vehicle –** William Hill

Agenda (cont.)

Ground System Development and Operations – William Hill

Exploration Technology Development - Andre Sylvester

***Advanced Exploration Systems –** Chris Moore

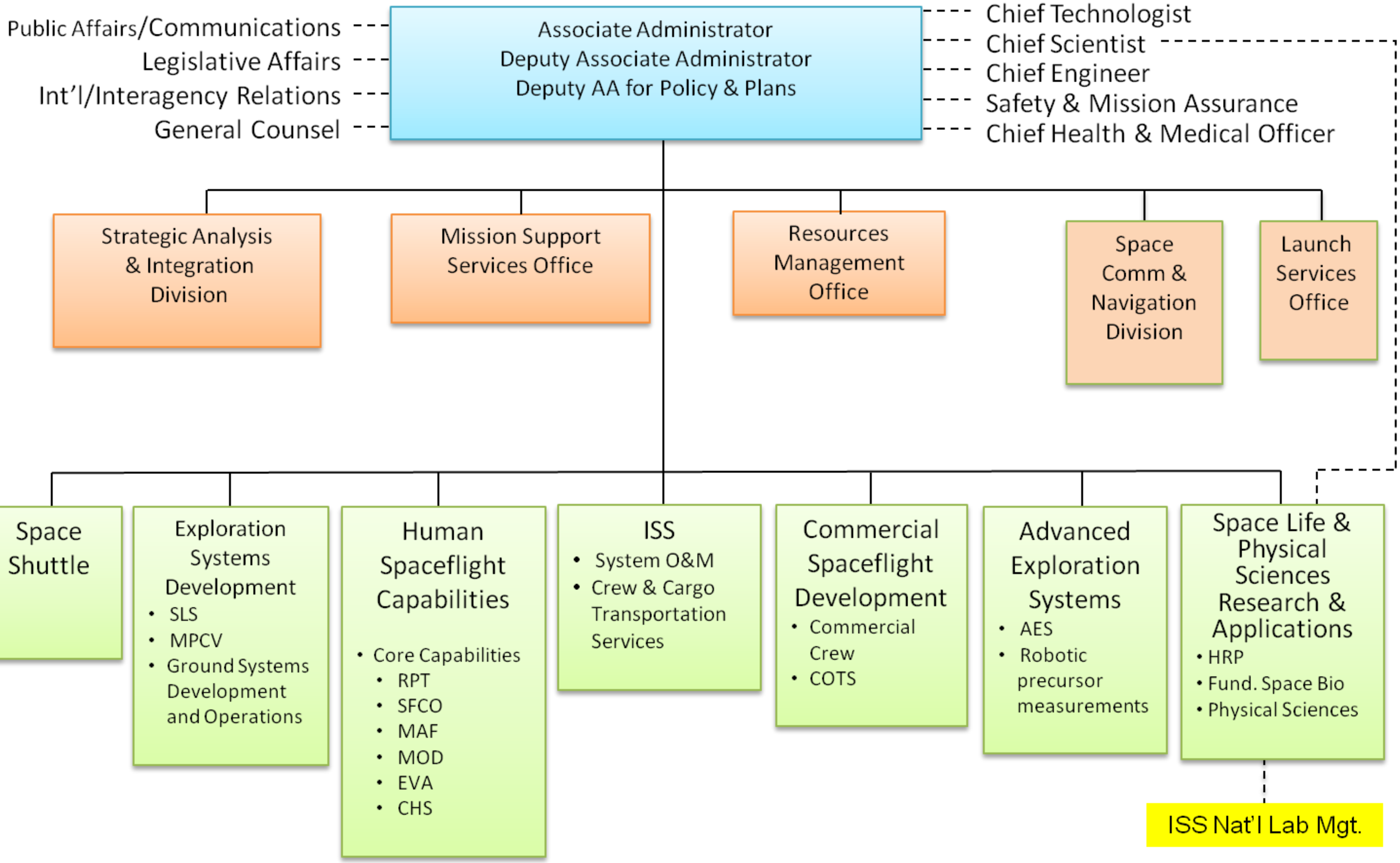
International Space Station (ISS) Operations and Utilization plans – Mark Uhran

ISS Robotics Capabilities and Demonstrations – Ronald Ticker

Status of Commercial Crew/Cargo – Phil McAlister

HEOMD Status

Human Exploration & Operations: Organization



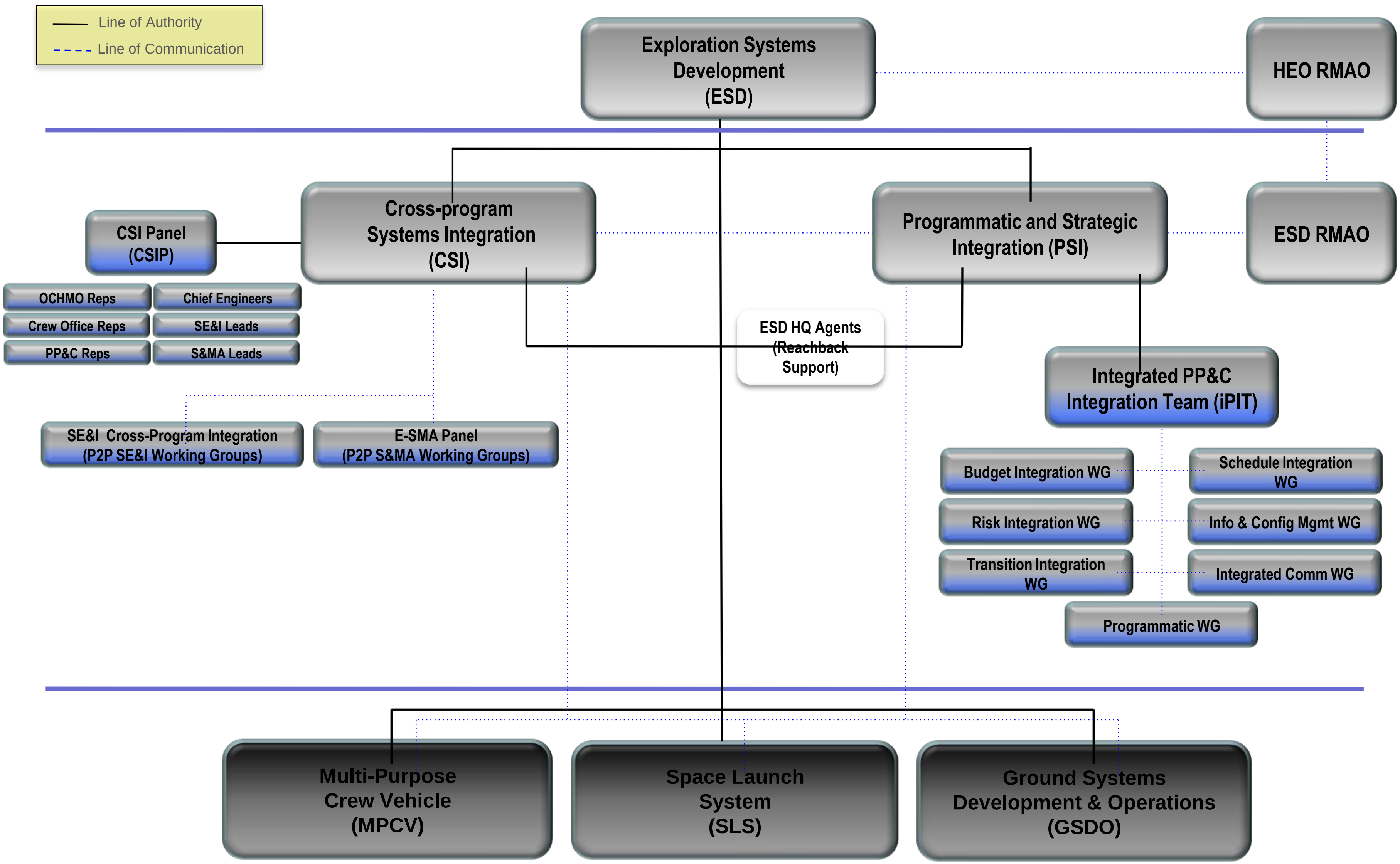
Human Exploration and Operations
Program Financial Plan
FY 2013 President's Budget Request Structure

Budget Authority ($ in Millions)	FY 2011**	FY 2012**	FY 2013	FY 2014 (Notional)	FY 2015 (Notional)	FY 2016 (Notional)	FY 2017 (Notional)
Human Exploration and Operations (HEO)	**9,237.7**	**7,931.5**	**7,946.0**	**8,111.6**	**8,111.6**	**8,111.6**	**8,111.6**
Exploration	**3,925.3**	**3,724.3**	**3,932.8**	**4,076.5**	**4,076.5**	**4,076.5**	**4,076.5**
Exploration Systems Development (ESD)	2,982.1	3,007.5	2,769.4	2,913.1	2,913.1	2,913.1	2,913.1
Orion Multi-Purpose Crew Vehicle (MPCV)	1,196.0	1,200.0	1,024.9	1,028.2	1,028.2	1,028.2	1,028.2
Space Launch System (SLS)*	1,786.1	1,503.0	1,340.0	1,429.3	1,429.3	1,429.3	1,429.3
Exploration Ground Systems (EGS)		304.5	404.5	455.6	455.6	455.6	455.6
Commercial Spaceflight Program	606.8	406.0	829.7	829.7	829.7	829.7	829.7
Commercial Cargo	299.4						
Commercial Crew Program (CCP)	307.4	406.0	829.7	829.7	829.7	829.7	829.7
Exploration Research and Development (ERD)	336.4	310.8	333.7	333.7	333.7	333.7	333.7
Human Research Program (HRP)	154.7	157.7	164.7	164.7	164.7	164.7	164.7
Advanced Exploration Systems (AES)		153.1	169.0	169.0	169.0	169.0	169.0
Exploration Technology Development (ETD)	181.7						
Space Operations	**5,312.4**	**4,207.2**	**4,013.2**	**4,035.1**	**4,035.1**	**4,035.1**	**4,035.1**
International Space Station (ISS)	2,713.6	2,829.9	3,007.6	3,177.6	3,170.9	3,212.8	3,234.3
ISS Systems Operations and Maintenance	1,681.1	1,418.7	1,493.5				
ISS Research	175.7	225.5	229.3				
ISS Crew and Cargo Transportation	856.8	1,185.7	1,284.8				
Space Shuttle Program (SSP)	1,592.9	559.3	70.6				
Space and Flight Support (SFS)	1,005.9	818.0	935.0	857.5	864.2	822.3	800.8
Space Communications and Navigation (SCaN)	456.2	446.0	655.6	570.7	577.3	535.4	513.9
Launch Services Program (LSP)	83.3	81.0	81.2	82.8	82.8	82.8	82.8
Rocket Propulsion Test Program (RPT)	44.2	43.6	45.9	45.9	45.9	45.9	45.9
Human Space Flight Operations (HSFO)	112.5	107.6	111.1	111.1	111.1	111.1	111.1
21st Century Space Launch Complex (21st CSLC)	136.4	130.0	41.1	47.0	47.0	47.0	47.0
Space Technology Program	173.4	9.8					

*Total funding for SLS ($1,304.1M), EGS ($404.5M), and programmatic CoF ($140.4M) is $1,884.9M

** FY 2011 includes Space Technology and rescission is out; 2012 Op Plan as of 01/2012 different from Agency Briefing because includes requested transfer of $12M from EGS to SLS for CoF; FY 2012 and FY 2013 CoF in CECR Account; FY 2014 and out, CoF not transferred to CECR (may not add due to rounding)

ESD HQ Organization and Interfaces
ESD Division and Program-to-Program Integration



2013 Budget Highlights - ESD

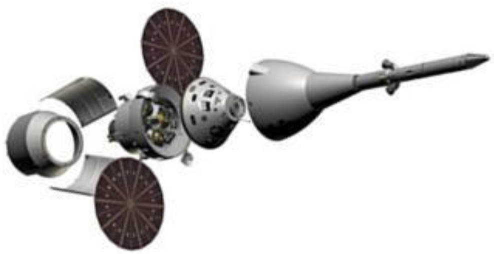
Outyears are notional

	2013	2014	2015	2016	2017
ESD	2,769	2,913	2,913	2,913	2,913

- By September 30, 2013, NASA will finalize cross-program requirements and system definition so that the first test flight of the Space Launch System (SLS) and Orion Multi-Purpose Crew Vehicle (MPCV) programs are successfully achieved at the end of 2017 in an efficient and cost effective way.
- Provides steady funding for SLS and Orion MPCV, along with associated Exploration Ground Systems (EGS).
- Exploration Systems Development (ESD) related funding is also in the Programmatic CoF ($143.7 million) which is included in the CECR account.
- Prioritizes work on existing contracts to maintain progress and minimize workforce disruptions.

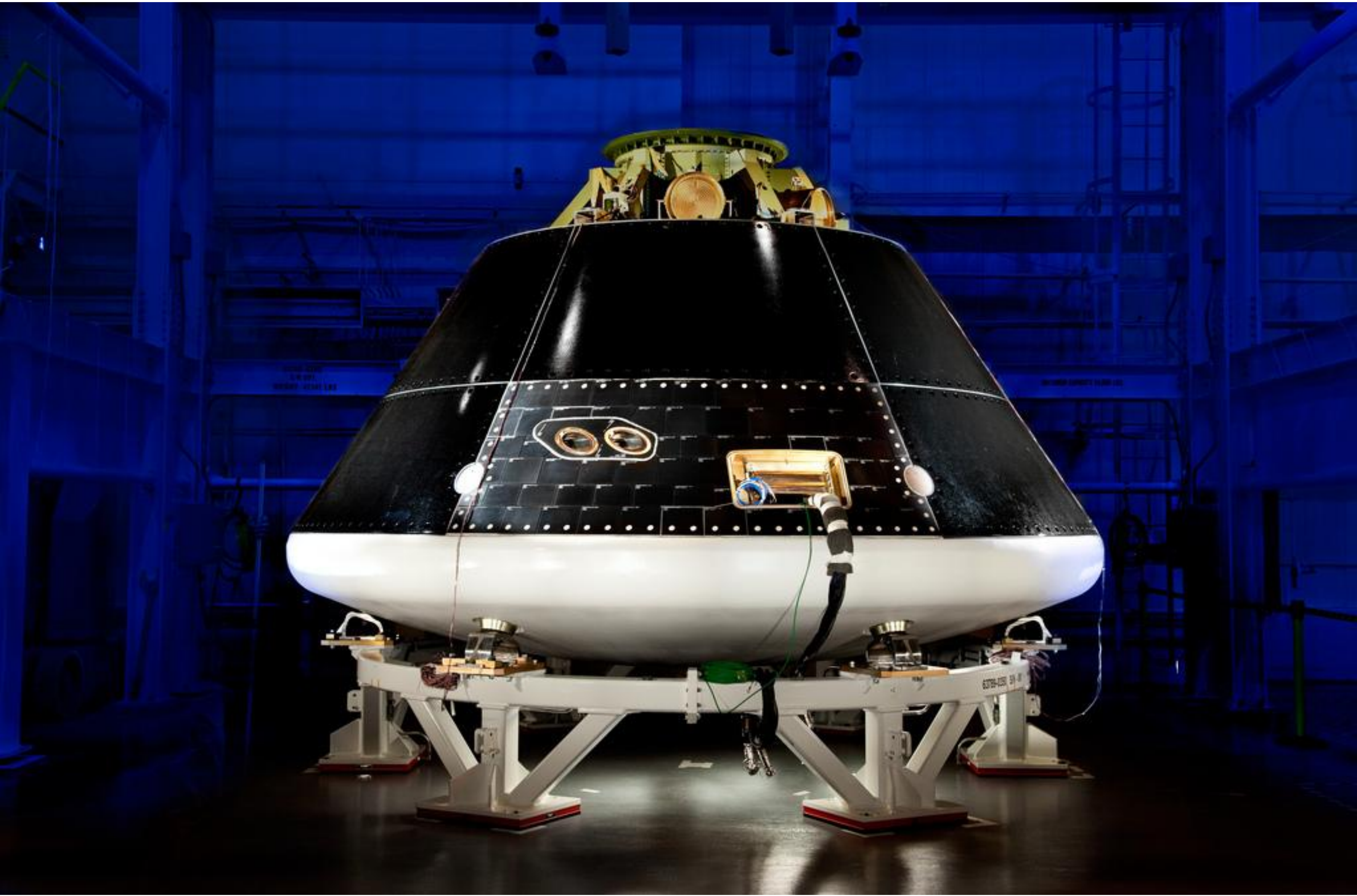
2013 Budget Highlights – ESD (cont.)

- Develops the heavy-lift vehicle ($1.88B in FY 13, including construction and exploration ground systems) that will be capable of launching the crew vehicle, other modules, and cargo for missions beyond low Earth orbit.
  - SLS selected architecture is an Ares/Shuttle-derived solution
- Corresponding modifications to the Kennedy Space Center launch range will be addressed by Exploration Ground Systems (EGS) program ($0.4B in FY 2013, including construction).
  - NASA will modify Launch Complex 39 to support 2017 launch



- Develops the Orion Multi-Purpose Crew Vehicle ($1.0B in FY13, including construction) that will carry crew to orbit, provide emergency abort capability on launch, sustain the crew while in space, and provide safe re-entry from deep space return velocities.
  - NASA designated the beyond-LEO version of Orion ("block 2") as the MPCV selected architecture, and will pace funding so the vehicle will be available in tandem with SLS.
  - Supports Exploration Flight Test 1 (EFT-1) in FY 2014 to reduce crew vehicle program cost and schedule risks.

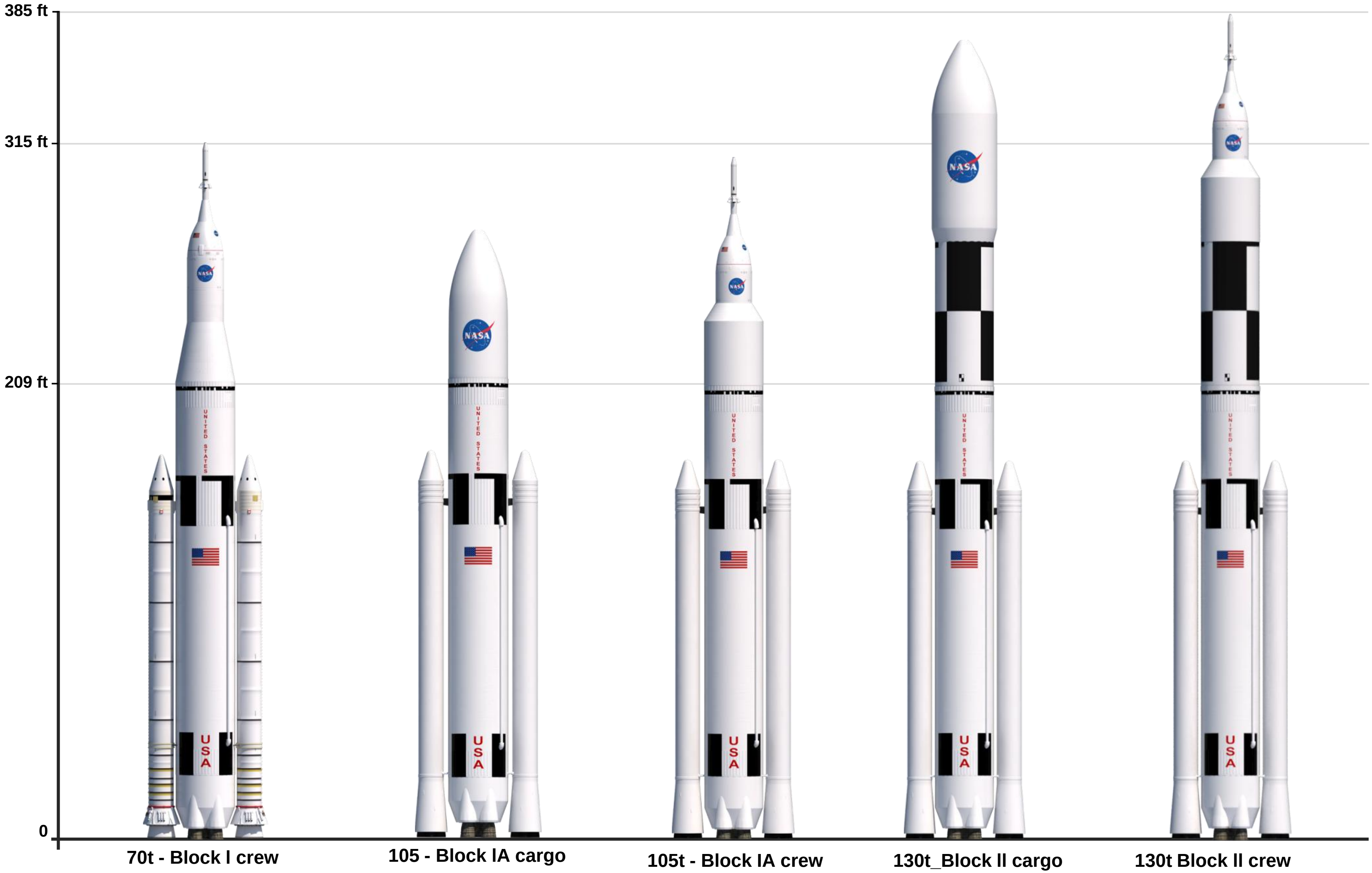
Orion MPCV
Ground Test Article



Orion MPCV Status

- EFT-1 Flight Test Undefinitized Contractual Action (UCA) issued Dec. 21, 2011; JOFOC Posted Jan. 5, 2012
- Initiated final CM barrel machining, completed cone and gore panel welding, delivered and assembled backbone
- Completed Drogue Chute Wind Tunnel Nov. 18, 2011
- Phase 1 Water Drop Testing Completed Jan. 6, 2012
- Conducted drop test of the Orion crew vehicle's entry, descent and landing parachutes on Feb. 29, 2012

SLS
Evolvable Configurations



Notional GSDO Range

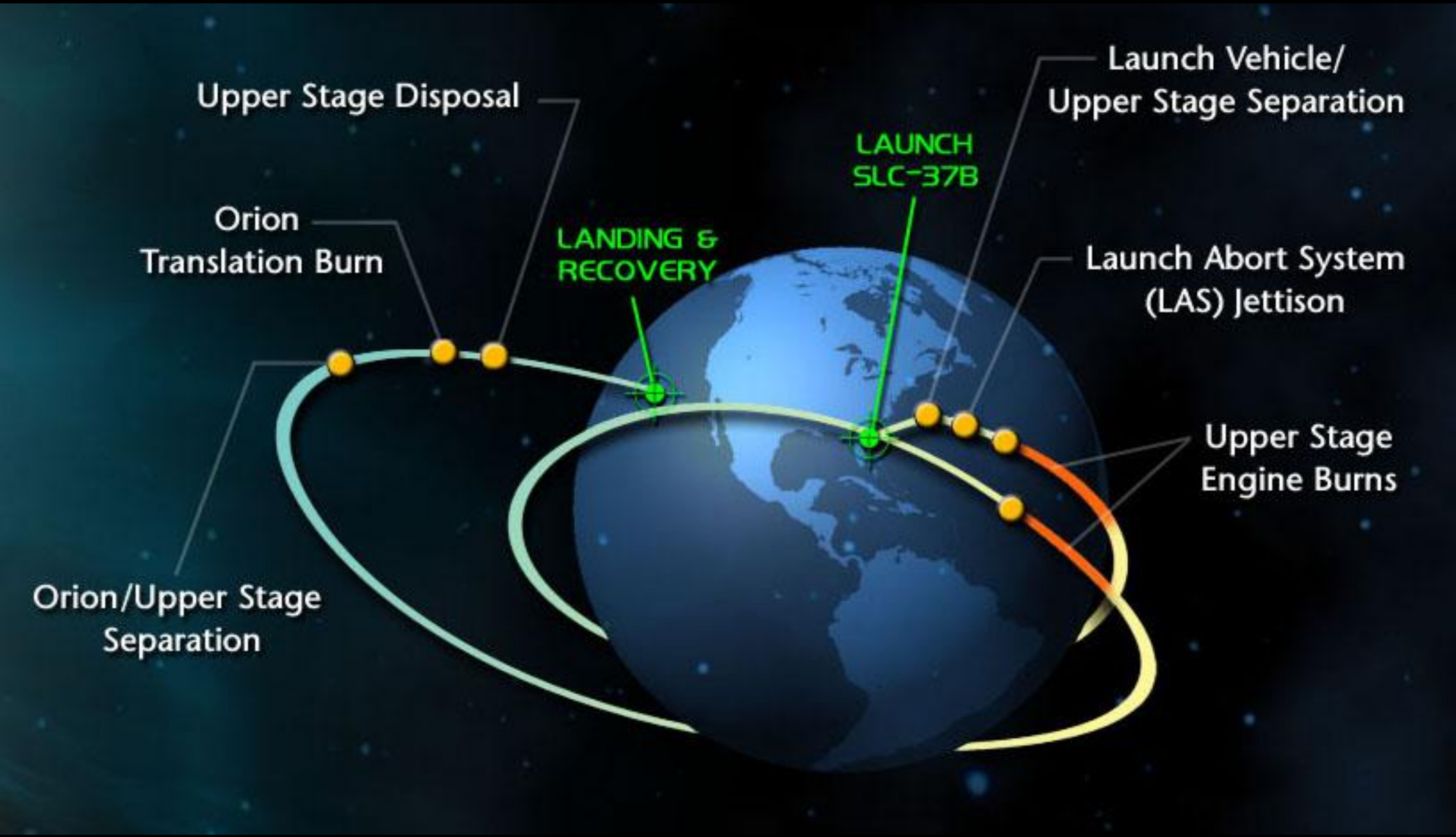
Overall Flight Test Strategy

Mission/Flight Test Objectives

- Flights are needed to test critical mission events and demonstrate performance in relevant environments
  - Abort, jettison, separation, chute deploy, Re-entry and TPS performance in BEO conditions, Integrated vehicle systems performance, and environments validation
  - Data collected from flights will be used to eliminate additional SLS test flights as the SLS configuration evolves
  - Dedicated flight tests will not be required for incorporation of competitive boosters, RS-25E, or the upper stage (with J-2X)

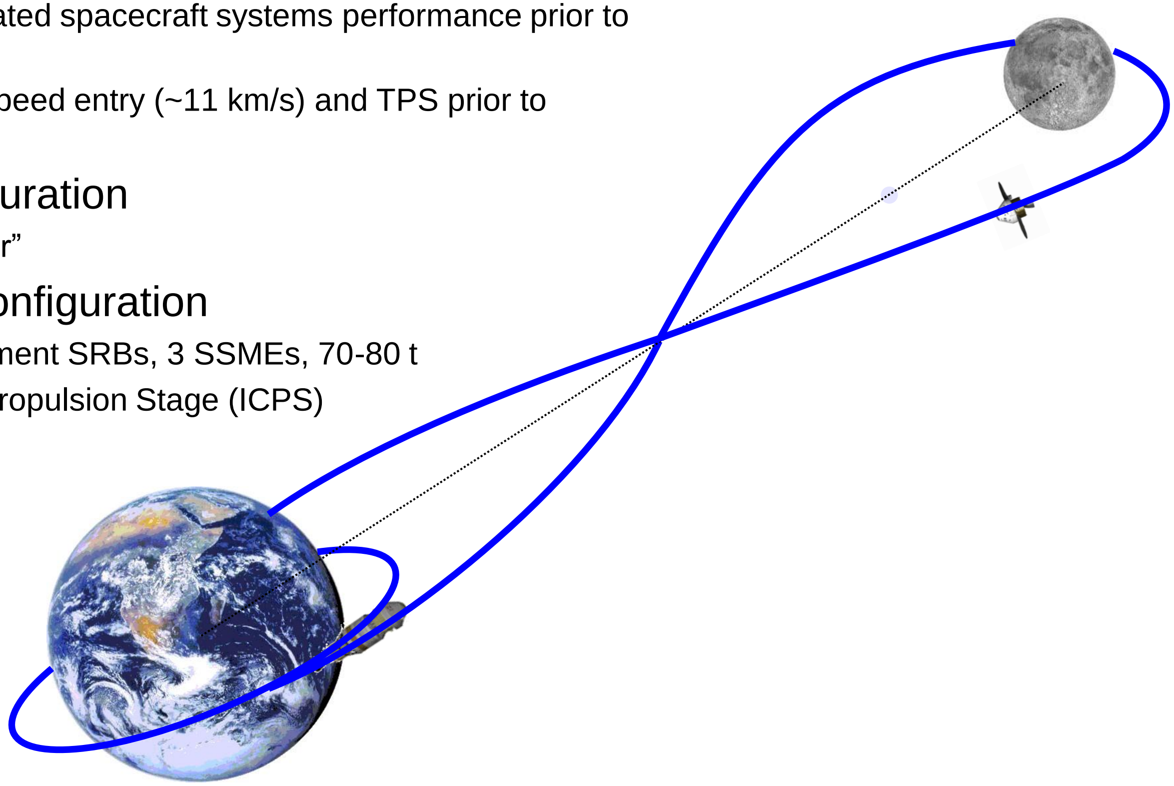
- Four missions/test flights planned to meet minimum mission/flight test
  - Exploration Flight Test-1 (EFT-1), an orbital, uncrewed test flight in 2014 provides MPVC system level tests and risk reduction opportunity
  - Ascent Abort-2 (AA-2), an abort test in high dynamic pressure environment
  - Exploration Mission-1 (EM-1), an Un-crewed BEO (lunar flyby) and EM-2, a crewed BEO flight (includes 3-4 day lunar orbit) will provide more system level testing and shakedown

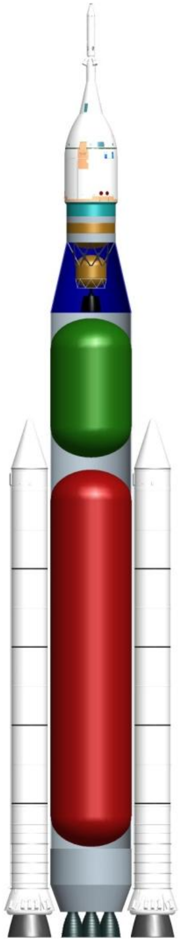
Exploration Flight Test 1



Exploration Mission – 1 (EM-1)
BEO Un-crewed Flight

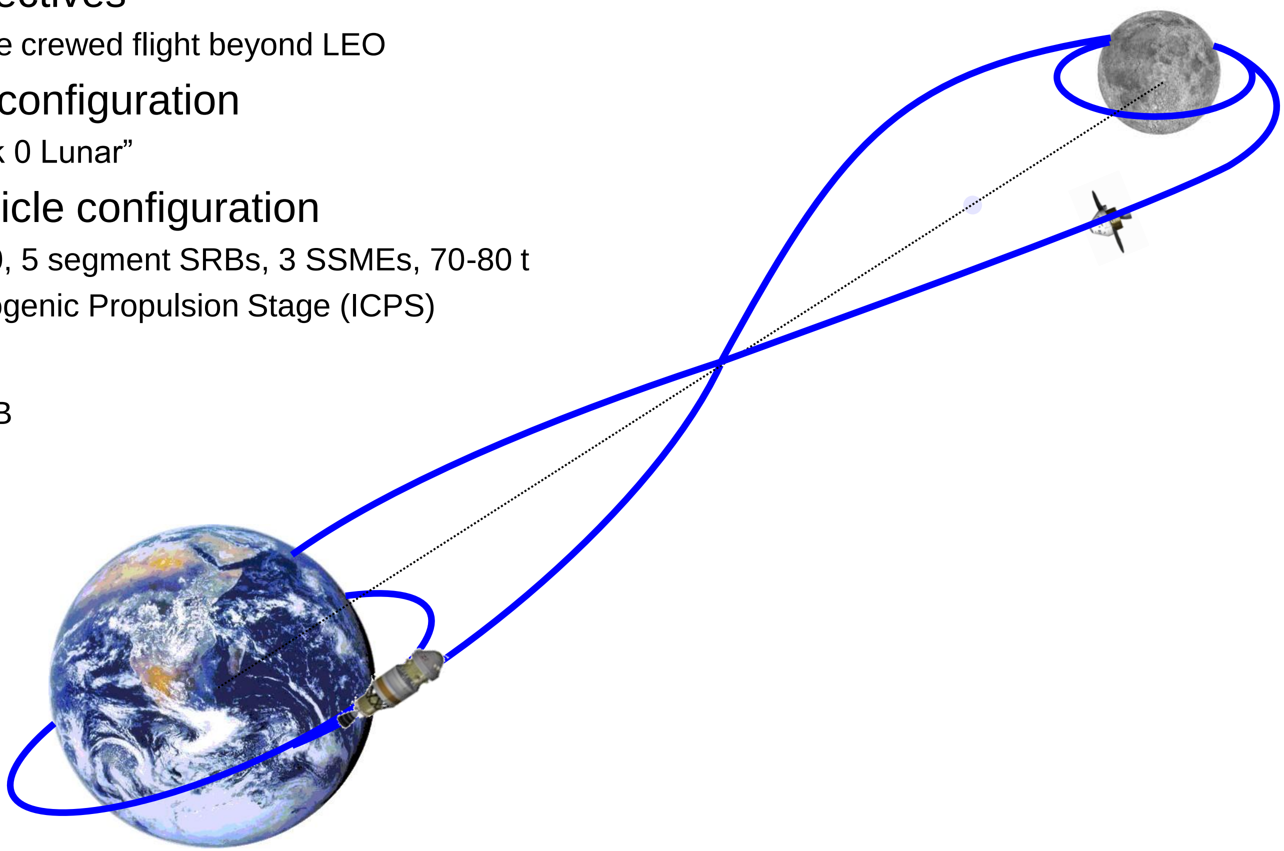
- Mission description
  - Un-crewed circumlunar flight – free return trajectory
  - Mission duration ~7 days
- Mission objectives
  - Demonstrate integrated spacecraft systems performance prior to crewed flight
  - Demonstrate high speed entry (~11 km/s) and TPS prior to crewed flight
- Spacecraft configuration
  - Orion "Block 0 Lunar"
- Launch vehicle configuration
  - SLS Block 0, 5 segment SRBs, 3 SSMEs, 70-80 t
  - Interim Cryogenic Propulsion Stage (ICPS)
- Launch site
  - KSC LC-39B

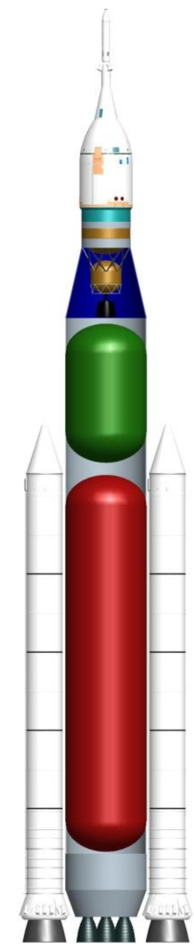




Exploration Mission – 2 (EM-2)
BEO Crewed Flight

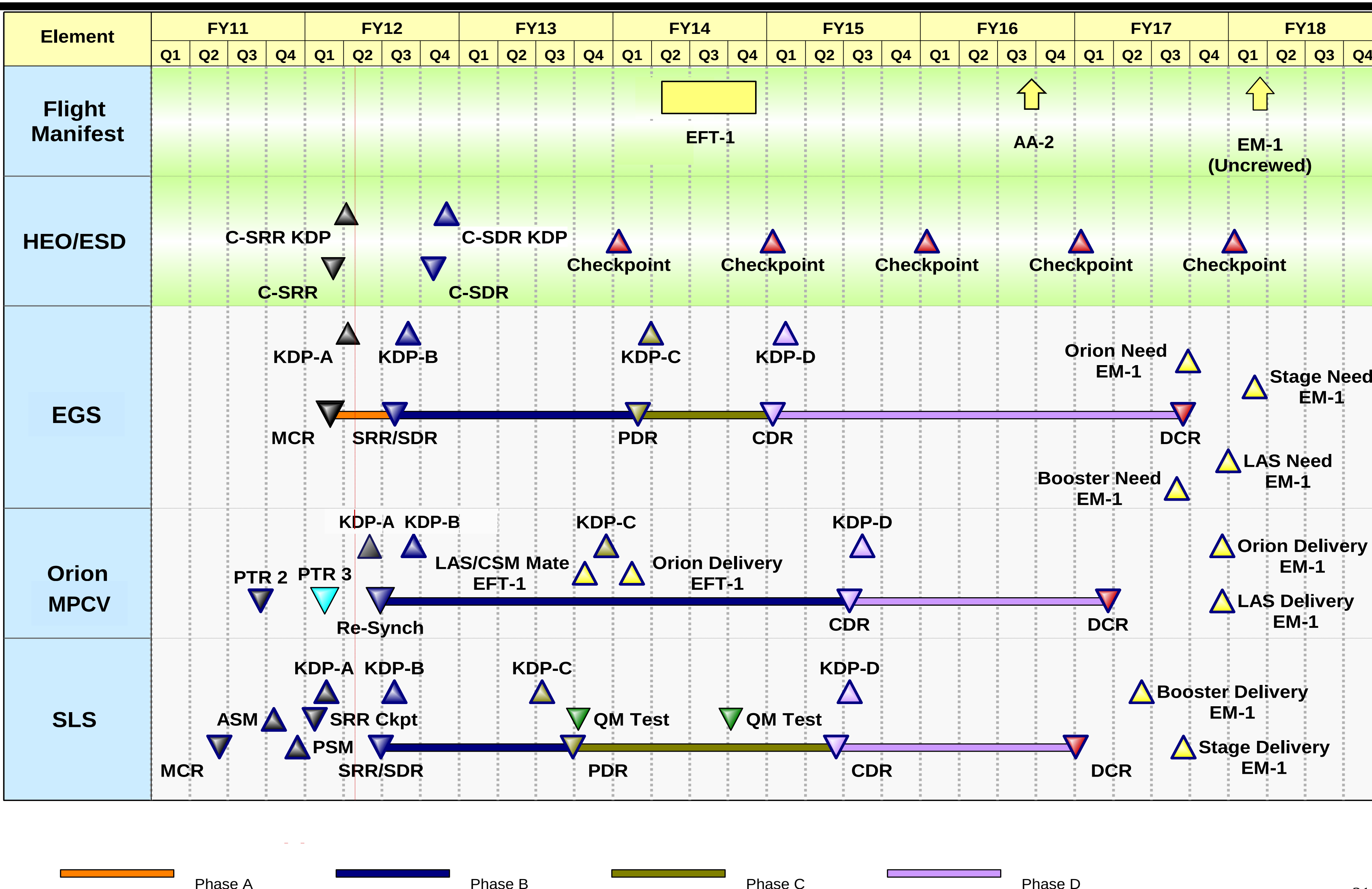
- Mission description
  - Crewed lunar orbit mission
  - Mission duration 10-14 days
- Mission objectives
  - Demonstrate crewed flight beyond LEO
- Spacecraft configuration
  - Orion “Block 0 Lunar”
- Launch vehicle configuration
  - SLS Block 0, 5 segment SRBs, 3 SSMEs, 70-80 t
  - Interim Cryogenic Propulsion Stage (ICPS)
- Launch site
  - KSC LC-39B





Exploration Systems Development

Current Integrated Summary Schedule



National Aeronautics and Space Administration

Advanced Exploration Systems

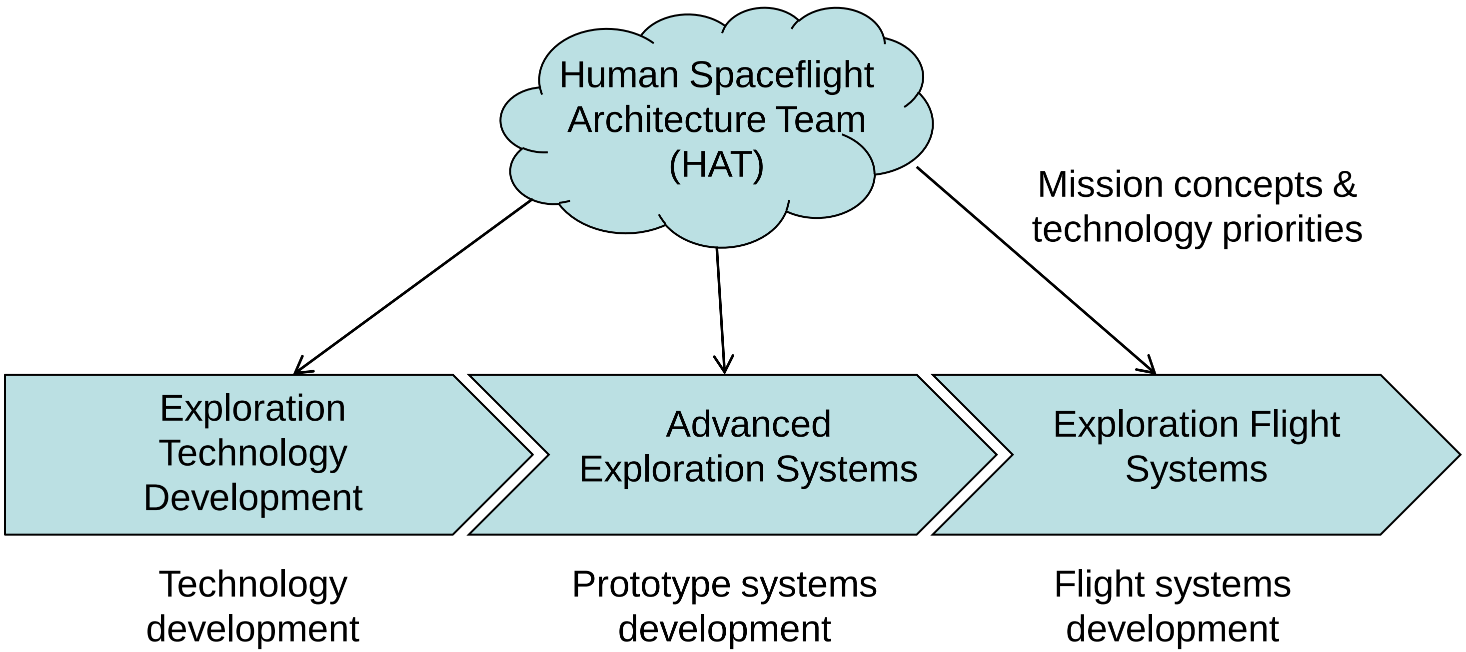
NASA Advisory Council

March 7, 2012

Dr. Chris Moore

NASA Headquarters

ETD and AES Activities Focus on Enabling New Capabilities for Exploration



Capability-Driven Architecture Elements

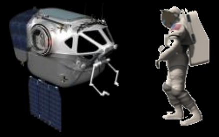
AES Key Capabilities

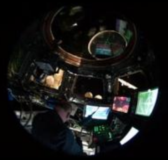
- AES builds a foundation of key capabilities to enable human and robotic exploration:
  - **Deep Space Habitation Capability**: Enable the crew to live and work safely in deep space on missions lasting over one year.
  - **Crew Mobility Capability**: Enable the crew to conduct “hands-on” surface exploration and in-space operations outside habitats and vehicles.
  - **Crew-Centered Operations Capability**: Enable more efficient mission and ground operations to improve affordability, and reduce the crew’s dependence on support from Earth.
  - **Robotic Precursors Capability**: Enable robotic precursor missions to characterize potential destinations for human exploration.

Timeline for AES Capabilities Development

2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 | 2020

Habitat Systems Life Support Radiation Protection Fire Safety Logistics Reduction	Deep Space Habitation Capability
MMSEV EVA Suitport	Crew Mobility Capability
Autonomous Mission Ops Integrated Ground Ops Analog Missions	Crew-Centered Operations Capability
Goldstone Radar RESOLVE Lunar Prospector Morpheus Lander / ALHAT RAD JRPA	Robotic Precursors Capability





AES Pioneers Innovative Approaches for Affordably Developing New Capabilities

- AES projects follow a “skunkworks-like” model for rapid development of prototype systems. Project teams are multi-disciplinary, highly collaborative, and work across organizational lines. Teams consist primarily of NASA personnel, and most of the work is performed in house.

- AES maintains critical competencies at the NASA Centers, and provides NASA personnel with opportunities to learn new skills and gain hands-on experience.

- AES leverages partnerships with external organizations to amplify investments. Partnerships include ESA for spacecraft fire safety, CSA for in-situ resource utilization, CERN for radiation sensors, and DOE for nuclear propulsion.

- Through NASA’s Center of Excellence for Collaborative Innovation (COECI), AES explores new models for problem solving using open innovation and crowd sourcing.
  - The NASA Tournament Lab sponsors competitions to engage the public in developing software to solve NASA challenges.
  - The COECI is working with OSTP to implement collaborative innovation across the Government.

AES Projects
Crew Systems

(Lead NASA centers)

- ***Crew Mobility Systems (JSC)***: Prototype Multi-Mission Space Exploration Vehicle (MMSEV) cabin and in-space mobility chassis to enable NEO and surface exploration.

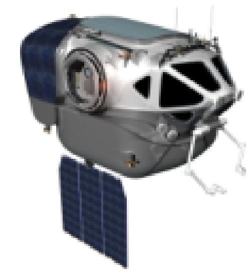
- ***Life Support Systems (MSFC, JSC)***: Improving the reliability of water recycling, air revitalization, and environmental monitoring systems using ground test beds.

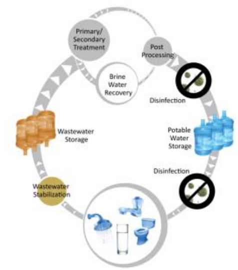
- ***EVA Systems (JSC)***: Next generation space suit, portable life support system, and suit port development leading to ISS flight demonstration.

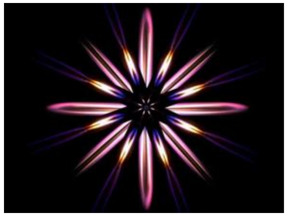
- ***Habitation Systems (JSC)***: Deep Space Habitat concept development, systems integration, and testing.

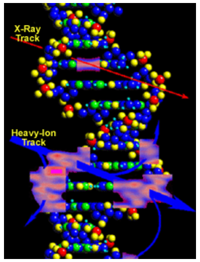
- ***Fire Safety (GRC)***: Large-scale, in-flight fire propagation and suppression experiment using ATV.

- ***Radiation Protection (JSC)***: Integrated demonstration of radiation shielding, radiation analysis tools, and advanced dosimetry sensors.





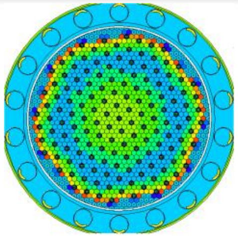




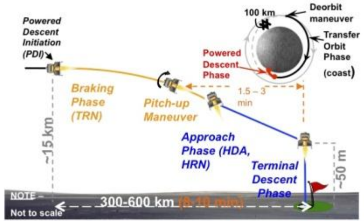
Vehicle Systems

(Lead NASA centers)

- ***Nuclear Propulsion (MSFC)***: Development of system concepts, ground test approaches, and reactor fuel elements for nuclear thermal propulsion.



- ***Autonomous Precision Landing (JSC)***: Flight test of ALHAT precision landing system on Morpheus Vertical Test Bed.



- ***Morpheus Vertical Test Bed (JSC)***: Small lander test bed for ALHAT, LOX-methane propulsion, and other vehicle systems

- ***Power Module (GRC)***: Modular batteries, fuel cells, and power systems for exploration flight systems.

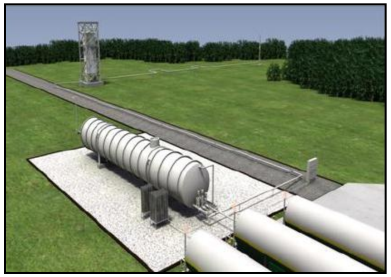
AES Projects
Operations

(Lead NASA centers)

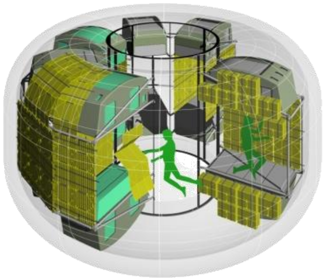
- ***Autonomous Mission Operations (ARC)***: Reducing crew dependence on ground-based mission control by automating flight dynamics and consumables management on ISS.

- ***Analogs (JSC)***: Testing prototype systems and operational concepts for NEO and Mars exploration in simulations, desert field tests, underwater environments, and ISS flight experiments.

- ***Ground Operations Systems (KSC)***: Demonstrating zero-loss cryogenic storage and intelligent systems health monitoringto reduce launch operations costs.



- ***Logistics (JSC)***: Reducing logistics storage volume and repurposing trash to reduce launch mass.



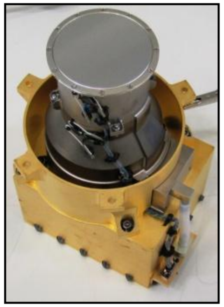
AES Projects

Robotic Precursor Activities

(Lead NASA centers)

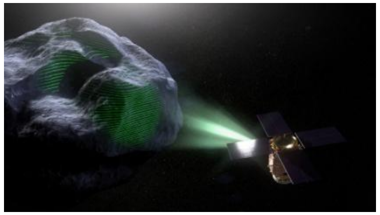
- ***Imaging Near Earth Asteroids (JPL)***: Using the Goldstone radar to image and characterize 20 NEAs at 4-meter resolution.

- ***Prospecting for Lunar Ice (KSC)***: RESOLVE in-situ resource utilization experiment to characterize lunar volatiles in partnership with Canadian Space Agency.



- ***Measuring the Mars Surface Radiation Environment (JPL)*****:** Supporting operations of Radiation Assessment Detector (RAD) on Mars Science Laboratory mission.

- ***Joint Robotic Precursor Activities (MSFC)*****:** Partnership with Science Mission Directorate to develop instruments for missions of opportunity and acquire strategic knowledge related to potential destinations for human exploration.



Summary

- The AES Program is pioneering new approaches for rapidly developing prototype systems, demonstrating key capabilities, and validating operational concepts for future human missions beyond Earth orbit.

- AES is exploring innovative approaches to rapidly develop and test prototype systems, and make missions more affordable.

- ISS is a key stepping stone for enabling deep space exploration. Many AES projects will evolve into larger integrated systems and mission elements that will be tested on ISS before we venture beyond Earth orbit.

- AES will incorporate new technologies developed by the OCT Space Technology Program.

- AES is implementing streamlined management practices to drive a rapid pace of progress, and use limited resources more effectively.

NAC HEOC's Proposed Recommendations to the NASA Advisory Council

Recommendation #1

Name of Committee:

NAC HEO Committee

Short Title of Recommendation:

Destination Selection

Recommendation:

Select a Human Spaceflight Destination ASAP

Recommendation #1 (cont.)

Major Reasons for the Recommendation:

With the approval of an SLS Booster, the Orion Spacecraft, and 21st Century Launch Complex planning can now begin on the destination mission. With initial crewed flight in 2021, the first operational flight could occur as early as 2022. Given the budget reality and development time for new hardware and software, (which is estimated to be at least 10 years) now is the time to pick a specific destination in order to focus the NASA, international agencies and contractor teams on a specific destination, such as Mars. In addition, the near and interim steps in order to achieve the ultimate objective should also be defined. We believe that a focused mission with a specific end objective, as has been the case for over 50 years for Human Spaceflight Programs, would also greatly benefit the NASA workforce, current and future domestic and international partners and the public stakeholders.

Recommendation #1 (cont.)

Consequences of No Action on the Recommendation:

Without selecting a mission we will delay a human flight to a destination. In addition, it will be difficult for the International Partners to determine where they can contribute to the human exploration program. Further, without a specific Program definition it will become increasingly difficult to get the American public excited about the future of NASA.

Recommendation #2

Name of Committee:

NAC HEO Committee

Short Title of Recommendation:

Specify Mission Objectives

Recommendation:

Develop specific mission objectives for Exploration Mission - 2 (EM-2) that justify the need for a crewed lunar orbit mission.

Recommendation #2 (cont.)

Major Reasons for the Recommendation:

The current mission objective for EM-2 is listed as, "Demonstrate crewed flight beyond LEO." Crewed flight beyond LEO was demonstrated more than 40 years ago in the Apollo program. NASA needs to show how EM-2 fits within the architecture for future human exploration beyond LEO and ensure that the objectives for a crewed lunar mission are consistent with the cost and risks involved.

Recommendation #2 (cont.)

Consequences of No Action on the Recommendation:

NASA leaves itself open to public criticism and loss of Congressional support if it cannot sufficiently justify the need for conducting a mission such as EM-2.

Recommendation #3

Name of Committee:

NAC HEO Committee

Short Title of Recommendation:

International Involvement

Recommendation:

Identify an existing ISS international partner or partners to accelerate expansion of international participation in future deep-space exploration planning. This expanded partnership will bring international resources to exploration and enhance sustainability. For any mission that is selected, we need additional hardware beyond the SLS and MPCV such as a lander, habitat, advanced propulsion systems, etc.

Recommendation #3 (cont.)

Major Reasons for the Recommendation:

History has shown that international partnerships have been effective. On ISS the partners have provided additional pressurized elements (i.e., laboratories, nodes and logistics modules), launch vehicles (i.e., Soyuz, Proton, Ariane-5, H2), cargo/crew transfer vehicles (i.e., Soyuz TMA, ATV, HTV), navigation systems, ground control centers, robotic systems, and training facilities.

Recommendation #3 (cont.)

Consequences of No Action on the Recommendation:

Limited US resources will delay exploration of the solar system. Additionally, strength of international treaties will benefit sustainability of exploration programs.

Recommendation #4

Name of Committee:

NAC HEO Committee

Short Title of Recommendation:

Contract Type

Recommendation:

The HEO Committee recommends that NASA modify the proposed fixed price Certification Contract to a more conventional Contract mechanism such as Cost plus Incentive Fee.

Recommendation #4 (cont.)

Major Reasons for the Recommendation:

Although NASA has stated that the RFP requirements are complete and no requirement changes are required it is the HEO Committee's experience that changes will occur and cost and/or schedule will be affected. Also with a fixed price contract NASA is likely to receive low bids that are not achievable.

Recommendation #4 (cont.)

Consequences of No Action on the Recommendation:

NASA would have to modify the contract to compensate the contractor or the contractor defaults. This could result in relying on remaining contractors and/or lack of a mission capability. Examples of Fixed contracts that have had problems and / or caused cancellations are; North American GPS; A-2 Fighter ETC; need input.

Recommendation #5

Name of Committee:

NAC HEO Committee

Short Title of Recommendation:

Creation of Subcommittee to NAC HEO Committee

Recommendation:

The NAC HEO Committee recommends the creation of a subcommittee of the HEO Advisory Committee that advises NASA on the research and educational needs that are required to support a plan for the long-range human exploration of space. The subcommittee should include a breadth of perspectives that encompass research and higher educational needs, not representation of specific disciplines.

Recommendation #5 (cont.)

Major Reasons for the Recommendation:

Efficient, coordinated and cost-effective advancement toward long-range space flight requires effective advance planning of an integrated research program that addresses both the physical and life sciences. A group of individuals who understand the Space Life and Physical Sciences Research programs would provide the strategic guidance that is required to achieve these goals, and would build strong supportive links with the academic and research communities that will be required to support these goals.

Recommendation #5 (cont.)

Consequences of No Action on the Recommendation:

NASA and HEOMD will lack the relationships with the academic community that are necessary to assure effective coordination of research with mission goals, and engagement with the educational community that shapes the scientists of tomorrow.